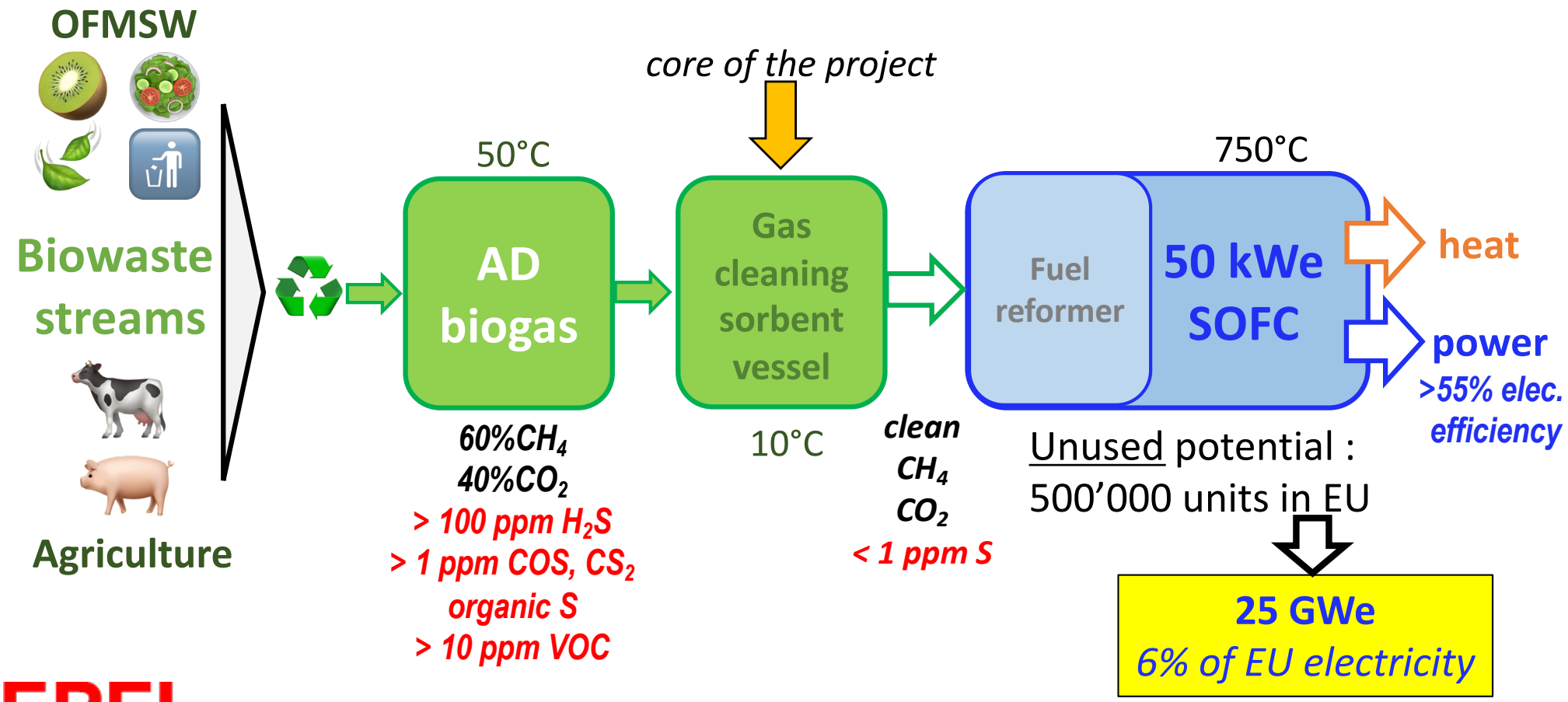
Waste2Watts
FCH-JU Project 826234

Jan Van herle
Ecole Polytechnique Fédérale de Lausanne, Switzerland

Waste2Watts project

- 2019/01 to 2021/12 - 3 year FCHJU project
- **low cost biogas cleaning** for coupling with **low cost SOFC** to prepare small scale biogas market entry for Solid Oxide Fuel Cells



SOFC cogenerators - status

NEW ENERGY GENERATION
SOLID POWER

1.5 kWe SOFC BlueGEN cogenerator for natural gas

- 63% *ac* electrical.eff.
- 26% heat efficiency

1500 units sold
(natural gas market)

Systems in development,
e.g. 50 kWe
*for natural gas & **biogas***

EPFL

W2W partners

Coordination – WP6
System Design – WP4

SOFC supply-WP3

Biogas resources – WP1

ADVISORY BOARD of biogas experts + biogas SMEs

Biogas cleaning – WP2

Testing – WP3

Biogas composition database

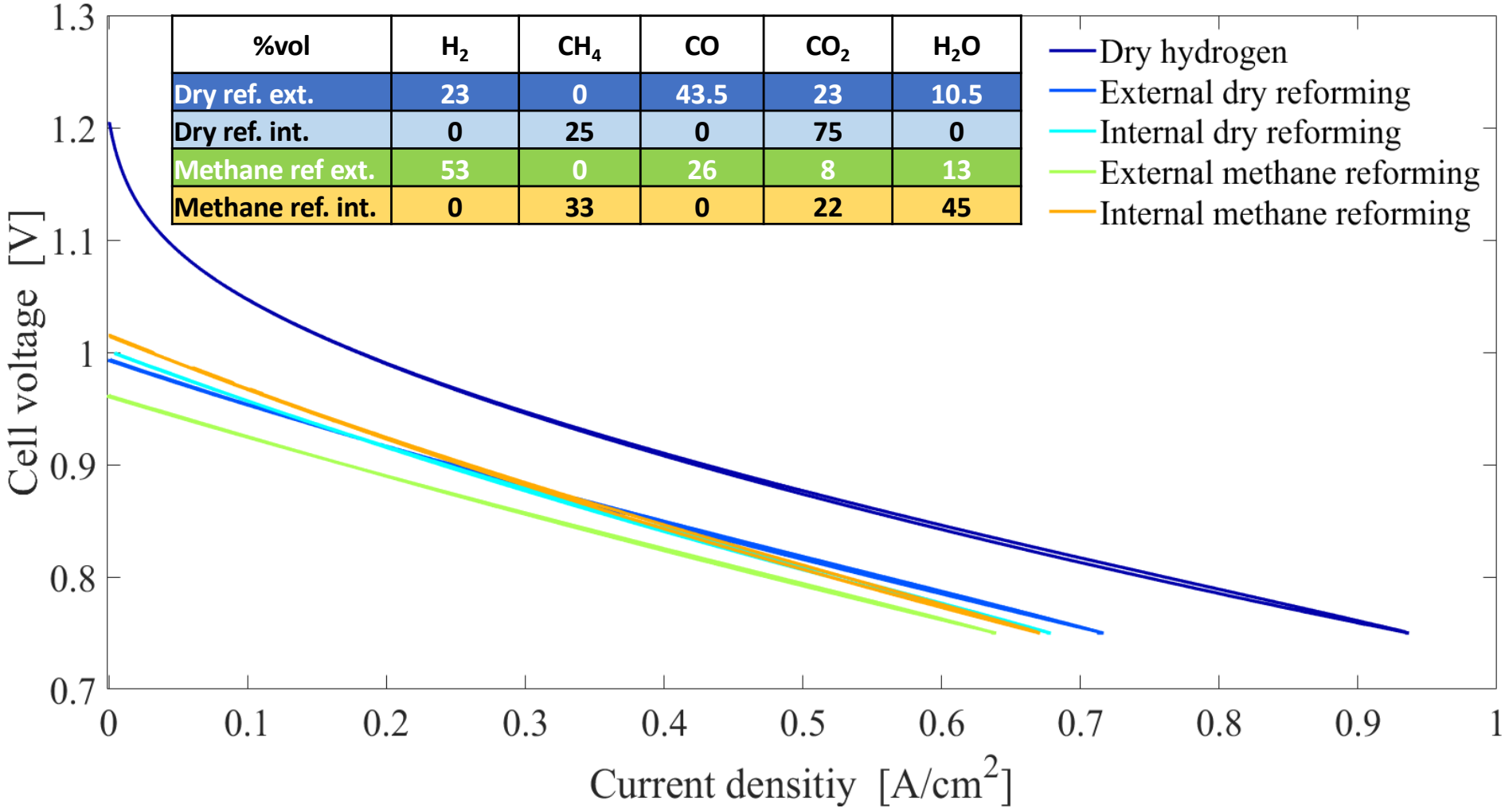
1. Compiled for the project
2. Completed with on-site measurements
   - e.g. H_2S and organic sulfur

Argonne National Laboratory	Abbreviations			Landfill characteristics/Comment	EPA Report [8]					Spiegel et al. (2003) [9]			Spiegel et al. (1997) [10]	Parker et al. (2002) [11]
	b.d. = below detection limit n.m = not measured p.m. = peaks missed STD = Standard deviation			Index # Landfill Site Activity Refuse - Type Refuse - Amount/Volume Gas production rate (SLPM) Analytical/Sampling	LFG-0 EPA Data for Municipal Solid Waste Landfills across U.S Pre-1992 Landfills Average information across U.S unknown unknown Grab Sampling, on-site					LFG-1 Groton, CT, U.S Closed, 1983 Typical of majority sites in U.S 2 million tons 11300 H_2S meter/(on-line, T.B)			LFG-2 Penrose, CA, U.S 3 closed, 1 open Typical of majority sites in U.S - 2300 GC/MS,GC/FPD (online, T.B)	LFG-3 Co-disposal landfill, U.K. Accepting waste since 1984 67% municipal, 33% trade waste not specified not specified Grab sampling (organosulfur, adsorbent)
				Comments	Background Information Document for Updating AP42 Section 2.4 for Estimating Emissions from Municipal Solid Waste Landfills EPA/600/R-08-116, September 2008					Analysis during fuel cell demonstration tests. H2S analysis as averaged from 28 individual wells[a]			Analysis performed during a 3 day period 25 days since GPU start-up. 6 measurements done during an 8 hour period	Sampling location in cells with 17 year old waste
	Class	#	Formula	Chemical Name	Data Points	min (ppm)	max (ppm)	Average (ppm)	STD (ppm)	min (ppm)	max (ppm)	Average (ppm)	Average (ppm)[b]	17 year old waste (ppm)
	Sulfur	11	H_2S	Hydrogen Sulfide	37	0.001	322.000	30.400	53.500	18	500	281	107	19.8
	Sulfur	12	CH_4S	Methanethiol (Methyl Mercaptan)	30	0.001	3.910	1.340	0.893			b.d.	2.96	
	Sulfur	13	COS	Carbonyl Sulfide	30	0.000	0.270	0.121	0.071			b.d.	0.164	
	Sulfur	14	CS_2	Carbon Disulfide	35	0.000	0.340	0.140	0.083			b.d.	<0.07	0.04
	Sulfur	15	C_2H_6S	Dimethyl Sulfide (DMS)	30	0.007	14.300	5.550	3.710			0.9	6.52	0.43
	Sulfur	16	C_2H_6S	Ethanethiol (Ethyl mercaptan)	31	0.000	0.833	0.189	0.188				0.47	
	Sulfur	17	$C_2H_6S_2$	Dimethyl Disulfide (DMDS)	26	0.000	0.420	0.129	0.097			b.d.	<0.07	<0.01
	Sulfur	18	C_3H_8S	Ethyl Methyl Sulfide	1	0.037		0.037						
	Sulfur	19	C_3H_8S	1-Propanethiol (n-propyl mercaptan)	23	0.000	0.473	0.116	0.118					
	Sulfur	20	C_3H_8S	2-Propanethiol (Isopropyl Mercaptan)	25	0.000	1.190	0.168	0.249					
	Sulfur	21	C_3H_6OS	1,3-Oxathiolane										
	Sulfur	22	C_4H_4S	Thiophene	2	0.124	0.571	0.348	0.316					<0.01
	Sulfur	23	$C_4H_{10}S$	Diethyl sulfide	1	0.086		0.086						
	Sulfur	24	$C_4H_{10}S$	Isopropyl Methyl Sulfide										
	Sulfur	25	$C_4H_{10}S$	Methyl Propyl Sulfide										
	Sulfur	26	$C_4H_{10}S$	2-Methyl-1-propanethiol (Isobutyl mercaptan)	1	0.170		0.170						
	Sulfur	27	$C_4H_{10}S$	2-Methyl-2-propanethiol (tert-Butylmercaptan)	1	0.324		0.324						
	Sulfur	28	$C_4H_{10}S$	1-Butanethiol (Butyl Mercaptan)										
	Sulfur	29	$C_4H_{10}S$	2-Butanethiol (sec-Butylmercaptan)										

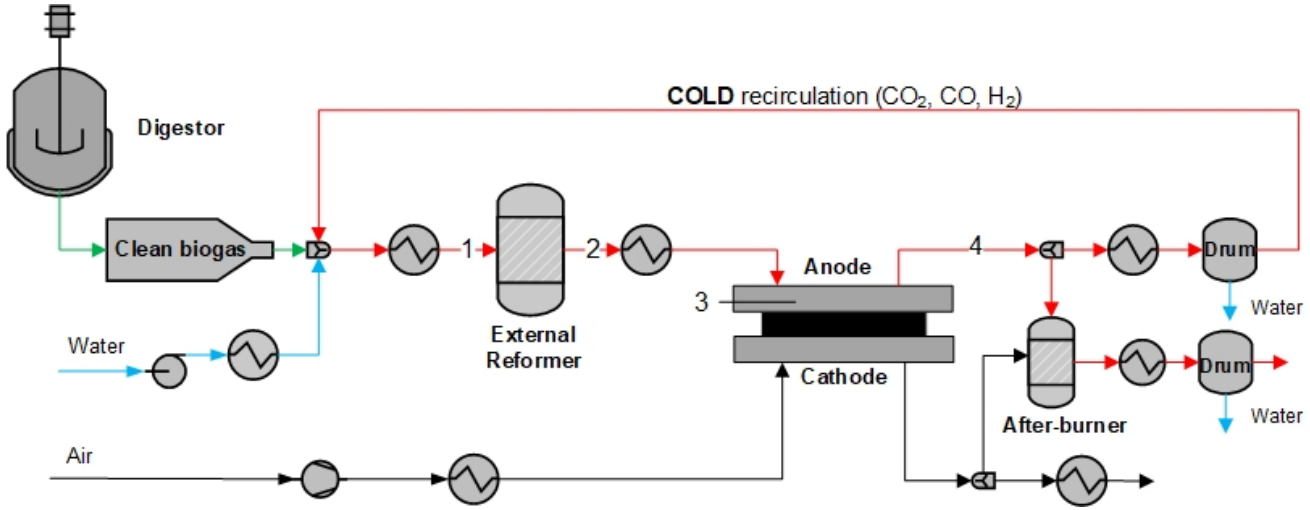
This basis is used to select and test (6) solid sorbents for cleaning of mixed gases: difficult compounds (H_2S, DMS, COS, CH_3S) in difficult matrix conditions (+VOC, Si).

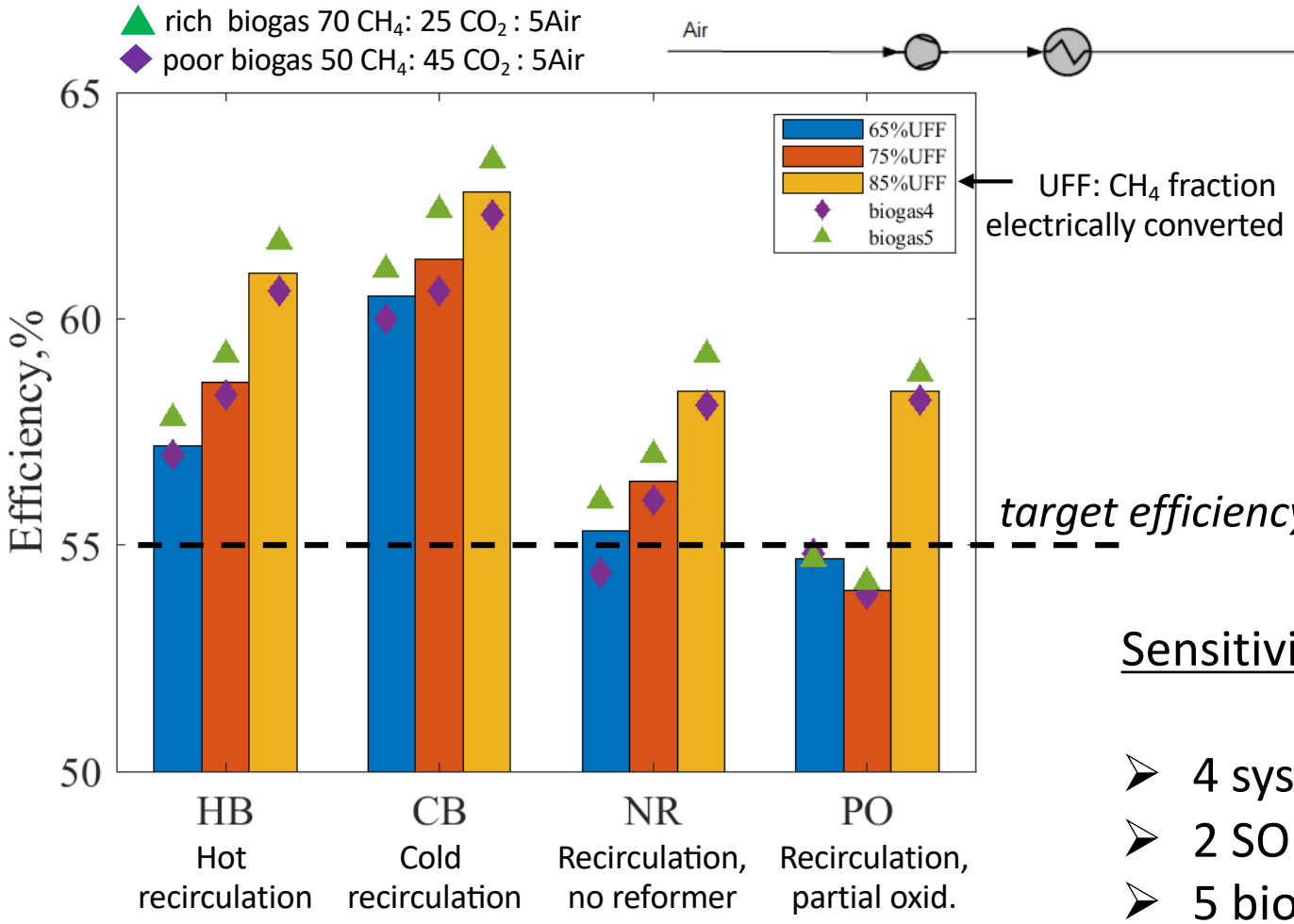
Cell test results

%vol	H_2	CH_4	CO	CO_2	H_2O
Dry ref. ext.	23	0	43.5	23	10.5
Dry ref. int.	0	25	0	75	0
Methane ref ext.	53	0	26	8	13
Methane ref. int.	0	33	0	22	45



Biogas SOFC CHP system





UFF: CH_4 fraction electrically converted

target efficiency

Sensitivity analyses performed:

- 4 system configurations
- 2 SOFC technologies
- 5 biogas compositions

EPFL

Small scale biogas SOFC market

SOFC units	Agricultural waste			OFMSW			
	XS + S (50 kWe)	M & L (200 kWe)	Installations agro	XS + S (50 kWe)	M (200 kWe)	L (500 kWe)	Installations OFMSW
EU-27	499783	111594	611377	ND	ND	ND	-
France	87007	27693	114700	15	156	244	414
Germany	57571	8372	65943	215	88	142	445
Italy	59452	3555	63007	25	103	145	273
Switzerland	6986	74	7060	128	38	7	173
F+D+IT+CH	211015	39694	250709	383	385	537	1305
GWe total	**25.0**	**22.3**	**47.3**				**0.365**

>50% of all current unused biogas potential lies in 50kWe scale

largely dominated by agro-biogas (98% of total)

Key message

- AD biogas = largely under-used resource
- often small scale (53% of unused EU-potential), mainly farms
  - ***50 kWe and smaller (≤ 20 m^3/h biogas flow)***
- ≉ no case for biomethane separation/injection, nor ICE
- the answer is Solid Oxide Fuel Cells
  - *>50% electrical efficiency*
  - *no pollution (SOx, NOx, CH_4-slip), no noise*
  - *no transport of low value fuel using diesel vehicles, but on-site use*
- 0.5 million sites ⇒ 25 GWe ⇒ 6% of EU electricity
- needs small scale digester development
- needs low cost biogas cleaning to remove sulfur compounds

Waste2Watts

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Traitement et valorisation de déchets et d'effluents organiques

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NEW ENERGY GENERATION SOLID POWER

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